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Walter Ransom Day, Jr.

DETERMINATION OF EGG FERTILITY BY MEASUREMENT OF DIELECTRIC PROPERTIES

A THESIS

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By

Walter Ransom Day, Jr.

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MEASUREMENT OF DIELECTRIC PROPERTIES

APPROVED: ____________________

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DATE APPROVED BY CHAIRMAN: Sept. 6, 1956

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I wish to express my sincere appreciation to Doctor B. J. Dasher and Professor P. T. Hutchison for their invaluable assistance in this research.

This work would not have been possible without the splendid co-operation of Mr. H. L. Tillman of Chemell's Hatchery, Gainesville, Georgia, who made available the eggs and incubators, assisted with the test hatches, and always offered encouragement.

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ABSTRACT

Throughout the history of the hatchery industry one of the greatest problems has been that of poor hatchability. Hatchability is a measure of the production efficiency of the hatching process and is defined as the ratio of eggs that hatch to eggs that are set, expressed as a percentage. The primary cause of poor hatchability is the lack of a means to separate infertile eggs from fertile eggs before they are placed in an incubator. If such a means of separation were available, a great reduction in operating cost could be realized. Infertile eggs would no longer have to be transported, handled, and incubated.

The dielectric properties of both fertile and infertile eggs have been investigated over a wide range of frequencies in this research. Finite values of dielectric constant and conductivity were not measured as only a relative value between eggs was required.

Power dissipation measurements were made on eggs at a frequency of four megacycles. The egg under measurement was placed in a radio-frequency field and the resultant power dissipation was measured. The readings were found to depend upon egg size, weight, and the position of the egg within the field.

Dielectric constant and conductivity measurements were made on eggs by means of a Q-Meter over the frequency range of 50 kilocycles to 210 megacycles. The results of these measurements indicated that fertile eggs had a higher dielectric constant and a lower conductivity than did infertile eggs. These differences also increased with the frequency of measurement.

Measurement of the dielectric constant of eggs was made at 500 megacycles by employing the dielectric properties of the egg to shift the frequency of an oscillator. The amount of frequency shift was proportional to the dielectric constant of the egg. These measurements revealed the presence of a new variable called polarization. The egg appears to be polarized in that its dielectric property reading is dependent upon its rotational position about its longitudinal axis. The property appears to be due to the eccentricity of the egg yolk.

Dielectric property measurements were made at 10,000 megacycles by employing microwave measuring techniques. The relative transmission property of the egg was measured with the longitudinal axis of the egg parallel to the wide dimension of the waveguide and was found to be only slightly effected by polarization. Two test hatches were conducted to determine the relation of transmission to fertility. The results of these hatches indicated that, on the average, infertile eggs have a higher relative transmission than fertile eggs. Relative transmission readings were found to decrease with an increase in egg weight and egg diameter. An increase in egg length caused an increase in the relative transmission readings.

No definite dividing line between the transmission readings of fertile and infertile eggs could be determined even after the readings were corrected for differences in egg size. This indicates that other variables must be detected and corrections made before this system of egg fertility measurement can be made practicable.

CHAPTER I

INTRODUCTION

The hatchery industry, which originated in the early civilizations of China and Egypt, is concerned with the artificial incubation and hatching of chicken eggs. Throughout the history of the hatchery industry one of the greatest problems has been that of poor hatchability. Hatchability is a measure of the production efficiency of the hatching process and is defined as the ratio of eggs that hatch to eggs that are set, expressed as a percentage. Poor hatchability may be caused by many things; such as improper nutrition of the flocks, cracked eggs, deformed eggs, disease, and improper incubation, but the greatest cause is infertile eggs. If a means were available to distinguish fertile eggs from infertile eggs before they were shipped to the hatchery, a great reduction in operating cost could be realized. Infertile eggs would no longer have to be transported, handled, and incubated. Present hatchery practice requires that the eggs be incubated for a period of 18 days before the infertiles are detected and removed. This detection is accomplished by passing a light beam through the egg and observing the presence, or absence, of an embryo.

In recent years, extensive investigation into the chemical constitution of the chicken egg has been carried out. A. L. Romanoff and H. J. Grover (1) made electrical conductivity measurements on both the yolk and the white of fertile and infertile eggs by means of an audio-frequency bridge. Their experiments indicated that the electrical conductivity of the yolk and the white of fertile eggs decreased, while the conductivity of the yolk and the white of infertile eggs increased with incubation. Work done by A. L. Romanoff and R. A. Sullivan (2) on the refractive index of egg white indicates a difference between fertile and infertile eggs. The refractive index and the dielectric constant of a material are related (3). This suggests a difference between the dielectric constant of fertile and infertile eggs.

Using this information as a basis, A. L. Romanoff and C. L. Cottrell (4) made dielectric measurements on fertile and infertile eggs at a frequency of 14 megacycles. Their results indicated that fertile eggs had a higher dielectric constant and a lower conductivity than infertile eggs. They also found that their readings were not only a function of fertility, but of egg weight and egg shape as well.

Measurements of the dielectric properties of the yolk and the white of fertile and infertile eggs over the frequency range of two to sixty megacycles were made by A. L. Romanoff and K. Frank (5). They found that the greatest difference in relative conductivity between the two parts of the egg occurred at 15 megacycles. The percentage difference between the readings of the dielectric properties remained approximately constant over the frequency range they employed.

By utilization of the results of these early experiments, the difference between the dielectric properties of fertile and infertile eggs has been further investigated in this research. Finite values of dielectric constant and conductivity were not measured, as only a relative value between eggs was required. Dielectric property measurements have been made from 50 kilocycles to 210 megacycles, at 500 megacycles, and at 10,000 megacycles. Power dissipation and dielectric constant measurements were made at 500 megacycles by using the capacity of an egg to shift the frequency of an oscillator. Dielectric properties were measured at 10,000 megacycles by employing microwave measuring techniques.

The readings obtained by the various methods of measurement were found to depend upon egg weight and egg size, as well as fertility. At the frequency of 500 megacycles and above, a new variable called polarization was discovered. The egg appears to be polarized in that its dielectric property reading is dependent upon its rotational position about its longitudinal axis. This property appears to be due to the eccentricity of the egg yolk and varies from egg to egg.

The greatest difference between fertile and infertile eggs was noted in their transmission property at 10,000 megacycles. Test hatches were conducted on the measured eggs and the results of these hatches are presented herein.

CHAPTER II

STRUCTURE OF THE CHICKEN EGG

A knowledge of the structure, both chemical and physical, of the chicken egg is essential to understanding the problems of determining fertility. The brief discussion given here is intended to give the reader only a general knowledge of this very complex subject. A thorough understanding would require training in embryology.

The chicken egg, as shown in Figure 1, consists of the shell (G), with its outer coating or cuticle and its inner membrane (H); the outer thin white (J); the thick white (K); the inner thin white (L); a film of thick white (F); and the yolk (C), bounded by its vitelline membrane (E). The yolk contains the germinal disc white yolk (D) and the blastoderm (M).

Contained in the four layers of white are the proteins ovalbumen, conalbumen, ovomucoid, ovomucin, and the chalazae (B). The chalazae is a dense ropy material that allows the yolk to spin on its longitudinal axis so that the germinal disc is always uppermost.

The yolk is of complex chemical composition, containing the proteins ovovitellin and ovolivetin, ovolecithin in close association with the proteins, cholesterol, carbohydrate, choline, alcohol, creative and creatinine, lactic acid, various salts, pigments, vitamins, enzymes, and other substances.

The shell, which is largely calcium carbonate, is sufficiently porous to allow for the respiration of the developing embryo. In the large end of the shell is found the air cell (A) whose function is to

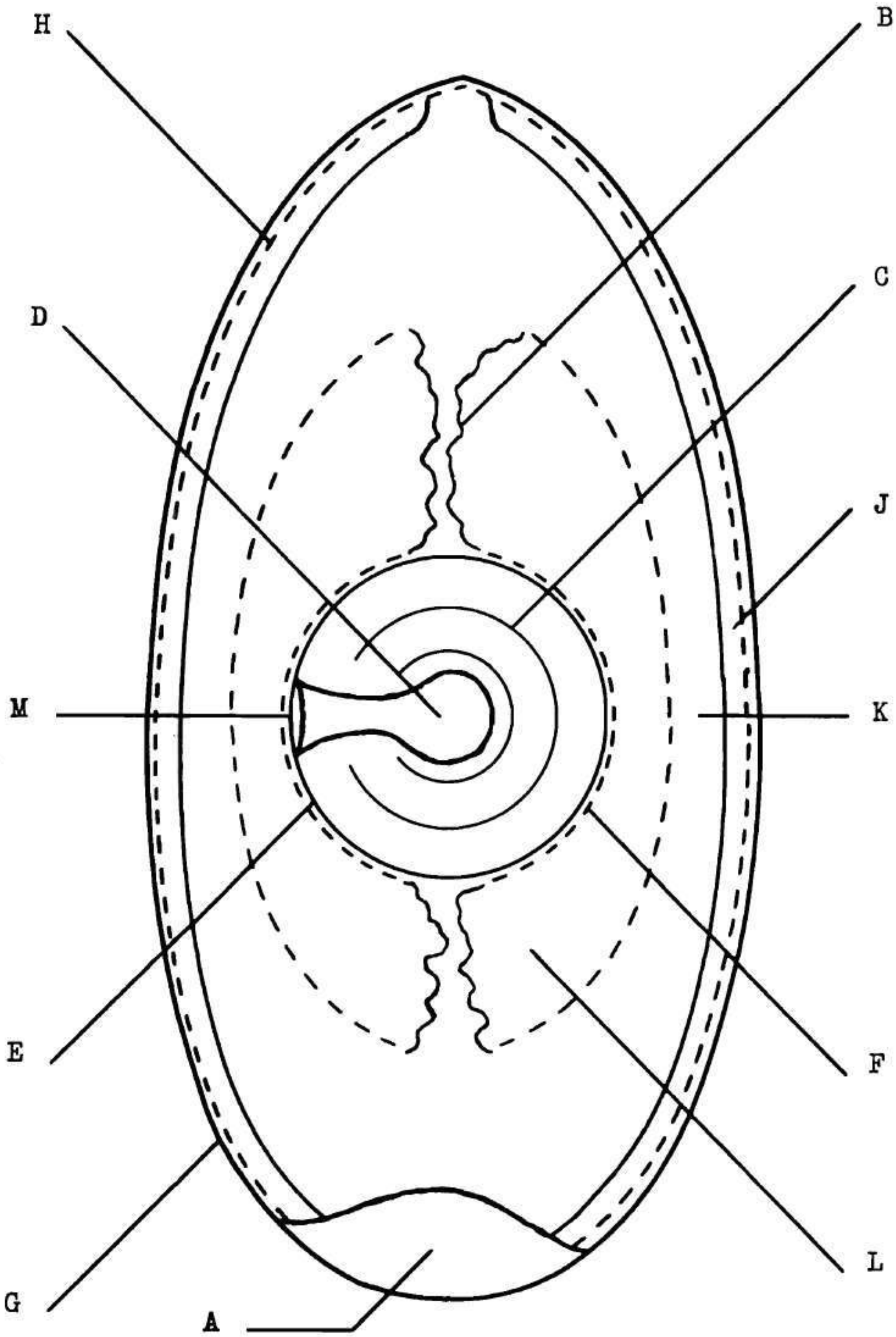

Fig. 1

STRUCTURE OF THE CHICKEN EGG

provide room for the developing embryo.

Formation of the egg begins in the ovarian tissue of the hen. Here the ovum, or yolk, is enclosed in the vitelline membrane. When the yolk has reached maturity, ovulation occurs and the yolk begins its journey through the female reproductive system. If the hen has been mated, and male sperm cells are present in the oviduct, fertilization takes place. Once a sperm has penetrated the ovum, the surface covering appears to undergo a chemical change and thickening which keeps out other sperm cells (6). The fertilized ovum starts cell division which continues during the approximately twenty-four hours the egg remains in the reproductive system. The blastoderm, or germ spot, increases in size and a change in the consistency of the white and yolk takes place.

After fertilization, the yolk continues its movement through the reproductive system where the thick white and chalazae are added. The shell membrane forms around this mass and determines the shape of the egg. Finally, the thin white and outer shell are added to complete the formation of the egg. The egg is now passed out of the body of the hen.

As long as the egg is held at a temperature above 82 degrees Fahrenheit, embryo development continues. The blastoderm spreads out over the yolk and three primary germ layers are formed. They are the ectoderm, entoderm, and the mesoderm. The skin, feathers, beak, claws, nervous system, and linings of the mouth and vent develop from the ectoderm. The entoderm gives rise to the respiratory and secretory systems and the linings of the digestive tract. Muscles, bones, blood, excretory and reproductive organs have their origin in the mesoderm.

Energy is required by the chicken embryo for its development. The sources for this energy are carbohydrates, proteins, and fats. Carbohydrate is first combusted because it requires no preparation. Proteins must be deaminated, fats must be desaturated, and probably the embryo in its earlier stages cannot do either of these things; but, on the other hand, glucose lies ready for use, and it is significant that what is combusted is free, not combines, carbohydrate (7).

Many other changes take place in the fertilized egg as the embryo develops. The hydrogen ion concentration of the yolk rises and the hydrogen ion concentration of the white decreases. The shell loses calcium and the calcium content of the interior of the egg increases. Enzyme action takes place in the development of the embryo, reducing substances of the egg to less complex structures so that they may be utilized by the developing embryo. Some enzymes are present in the egg and others are secreted by the embryo. Very little is definitely known about the action of hormones in the embryo development. Insulin and the estrogenic hormone are present in the egg yolk, and it is thought that the insulin plays an important part in the early carbohydrate metabolism. Many vitamins are present in the egg, provided the hen has received proper nutrition. The embryo synthesises the vitamins inositol, nicotinic acid, and ascorbic acid during its development.

A pronounced difference in the chemical composition exists between the fertile and infertile egg at the time of laying. The longer the eggs are held above a temperature of 82 degrees Fahrenheit, the greater this difference becomes.

CHAPTER III

LOW FREQUENCY DIELECTRIC MEASUREMENTS

With the experiments of A. L. Romanoff and C. L. Cottrell (8) as a basis, an attempt to measure the power dissipation difference between fertile and infertile eggs in the region of four megacycles was made. A block diagram of the system employed is shown in Figure 2. Radio frequency energy was supplied by a variable frequency oscillator driving a class C amplifier with a power input of approximately five watts. The amplifier was amplitude modulated at a frequency of 60 cycles per second. Inductively coupled to the tank circuit of the class C amplifier was the tuned circuit of the detector.

Detection was accomplished by the use of a type IN45 Germanium diode. Amplification of the detector output voltage was obtained by means of a resistance-capacity coupled amplifier. The output of this amplifier was displayed on a microvoltmeter. Power absorbtion differences between eggs were indicated by differences in meter readings.

The use of a voltage regulated power supply was essential in order to provide a stable frequency output from the oscillator and a fixed gain from the amplifiers.

Details of the tuned circuits involved in this system may be seen in Figure 3. Several schemes for placing the egg to be measured into the field were tried. Placing the egg in the tank coil of the class C amplifier proved to be unsatisfactory in that the distributed capacity of the egg detuned the amplifier. The power output of the amplifier was reduced,

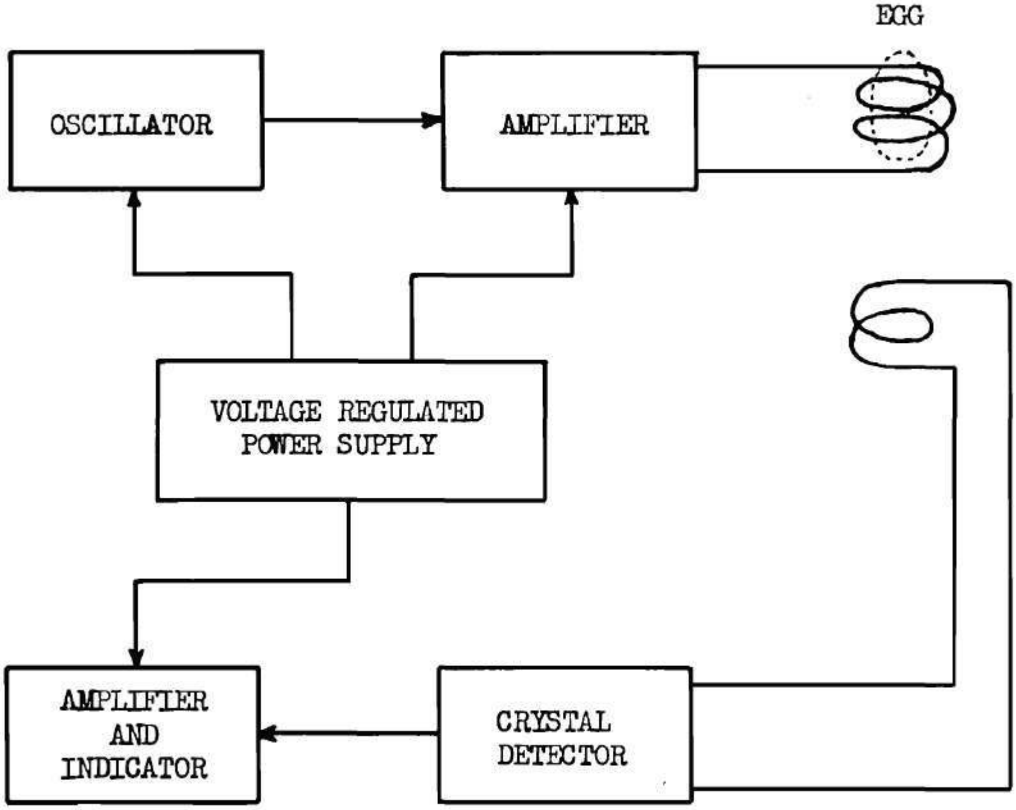

Fig. 2

BLOCK DIAGRAM OF LOW FREQUENCY SYSTEM
FOR MEASURING POWER DISSIPATION OF AN EGG

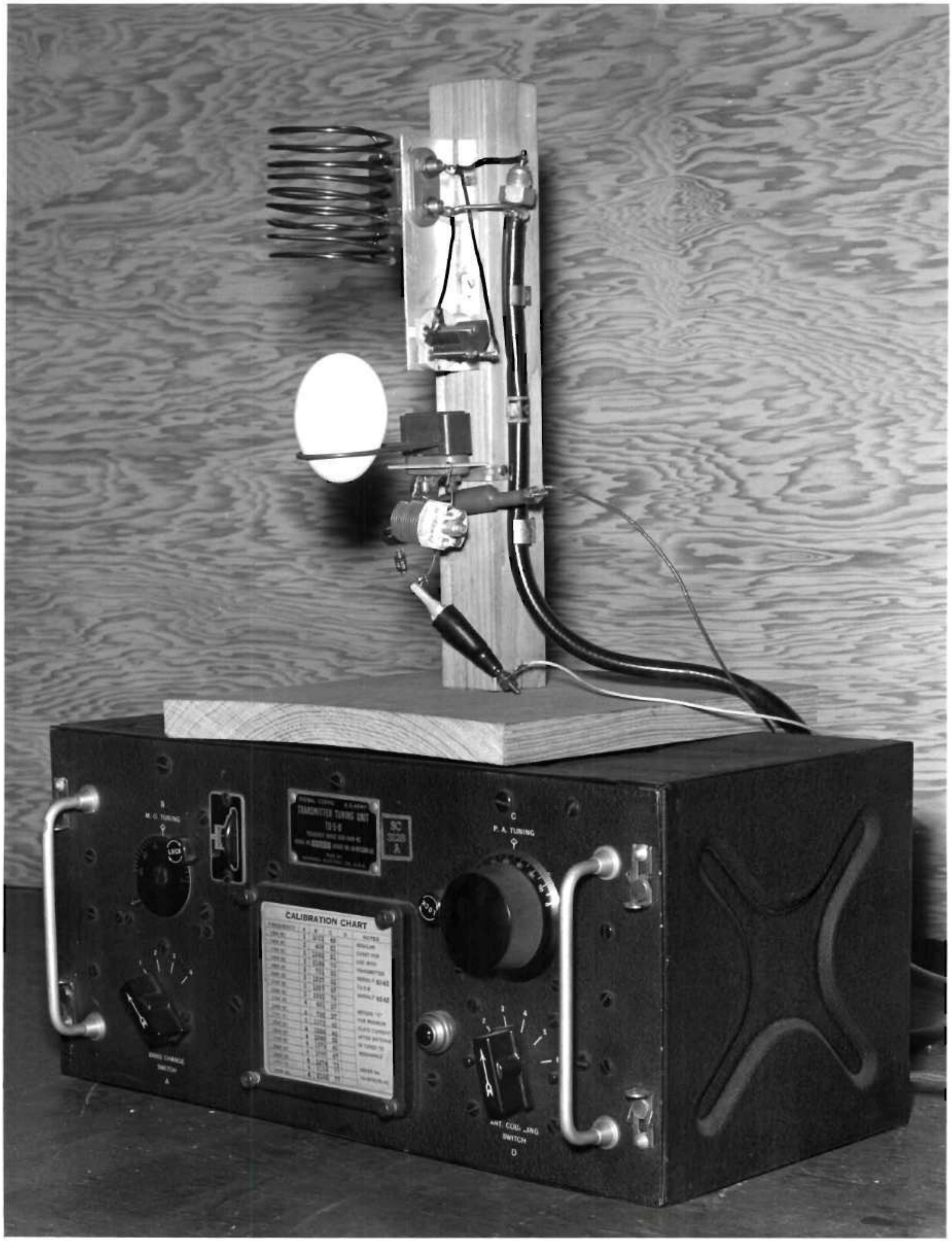

Fig. 3 LOW FREQUENCY SYSTEM FOR MEASURING POWER DISSIPATION OF AN EGG

and the reading of the egg was meaningless.

Locating the egg in a paraffin cradle in the field between the two coils was also attempted. This arrangement, though an improvement, gave poor sensitivity. This may be attributed to the fact that not all the flux lines linking the two coils passed through the egg.

Placement of the egg in the detector coil, as shown in Figure 3, gave the greatest sensitivity. Some detuning of the detector resulted from this arrangement but it was nearly constant for each egg and could be tolerated.

Evaluation of this system of measurement has shown it to be unsatisfactory for determining infertile eggs from fertile eggs. The readings obtained are not only functions of fertility but also of weight, physical dimensions, and the egg's position in the field. Tilting the egg from a position normal to the windings of the coil caused a large error to be introduced into its reading. Non-uniformity of the field within the coils gives rise to this error.

Data taken on known infertile eggs and probable fertile eggs by this system of measurement are not included in this dissertation, as no definite correlation between the many variables could be established.

An attempt to measure the dielectric constant and conductivity difference between fertile and infertile eggs, as a function of frequency, was made using the Boonton Model 160A and 170A Q-Meters. A test capacitor was constructed from two brass plates, two inches long and one and one-half inches high, with a paraffin egg cradle between them. The test capacitor and a coil, with sufficient inductance to resonate with it at the frequency of measurement, were connected to the Q-Meter. The Q-Meter was tuned to resonance and the vernier capacity dial reading was recorded. An egg was then placed in the cradle of the test capacitor. This had the effect of replacing the air dielectric between the plates with that of the egg. Re-resonating of the Q-Meter was accomplished by adjustment of the vernier capacity dial. The difference between the capacity dial readings is a measure of the dielectric constant of the egg, as dielectric constant and capacity are directly proportional. Relative conductivity between eggs is indicated by their Q readings. Eggs with a higher conductivity are more dissipative and thus have a lower Q.

Measurements were made on two dozen known infertile eggs and two dozen probable fertile eggs of the same weight. Readings were taken from 50 kilocycles to 210 megacycles. Negligible difference between fertile and infertile eggs was observed from 50 kilocycles to 30 megacycles. Above 30 megacycles, the difference between eggs became pronounced. The average values of the readings of capacity and Q, as functions of frequency, are shown in Figures 4 and 5, respectively.

Fertile eggs had a higher capacity, or dielectric constant, than did infertile eggs. Infertile eggs had a higher conductivity than did fertile eggs. The results of these measurements are in accord with the results of experiments cited in Chapter I.

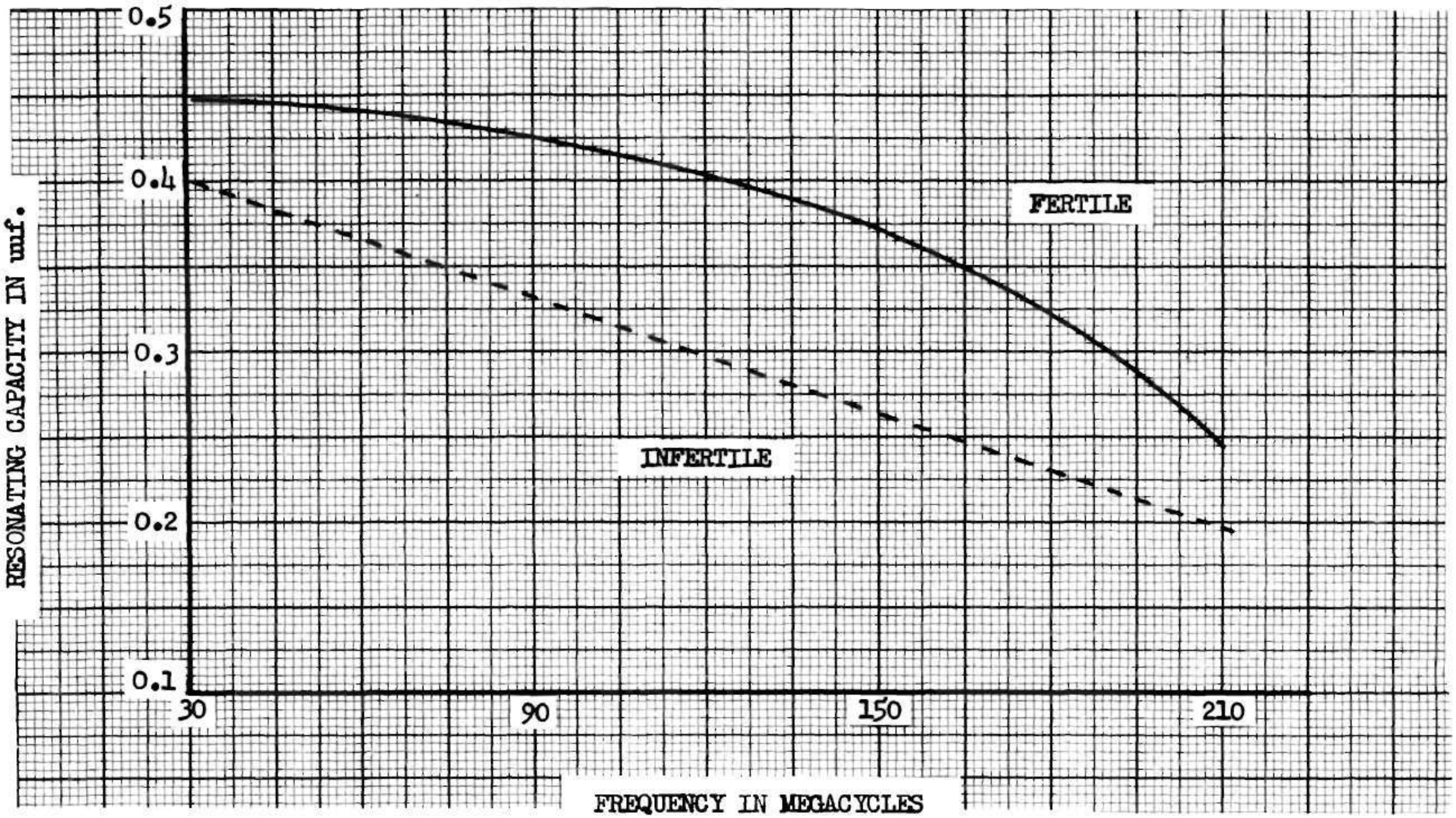

Fig. 4

PLOT OF RESONATING CAPACITY VS. FREQUENCY FOR 27 OZ./DOZEN CHICKEN EGGS AS MEASURED WITH BOONTON Q-METERS 160A & 170A

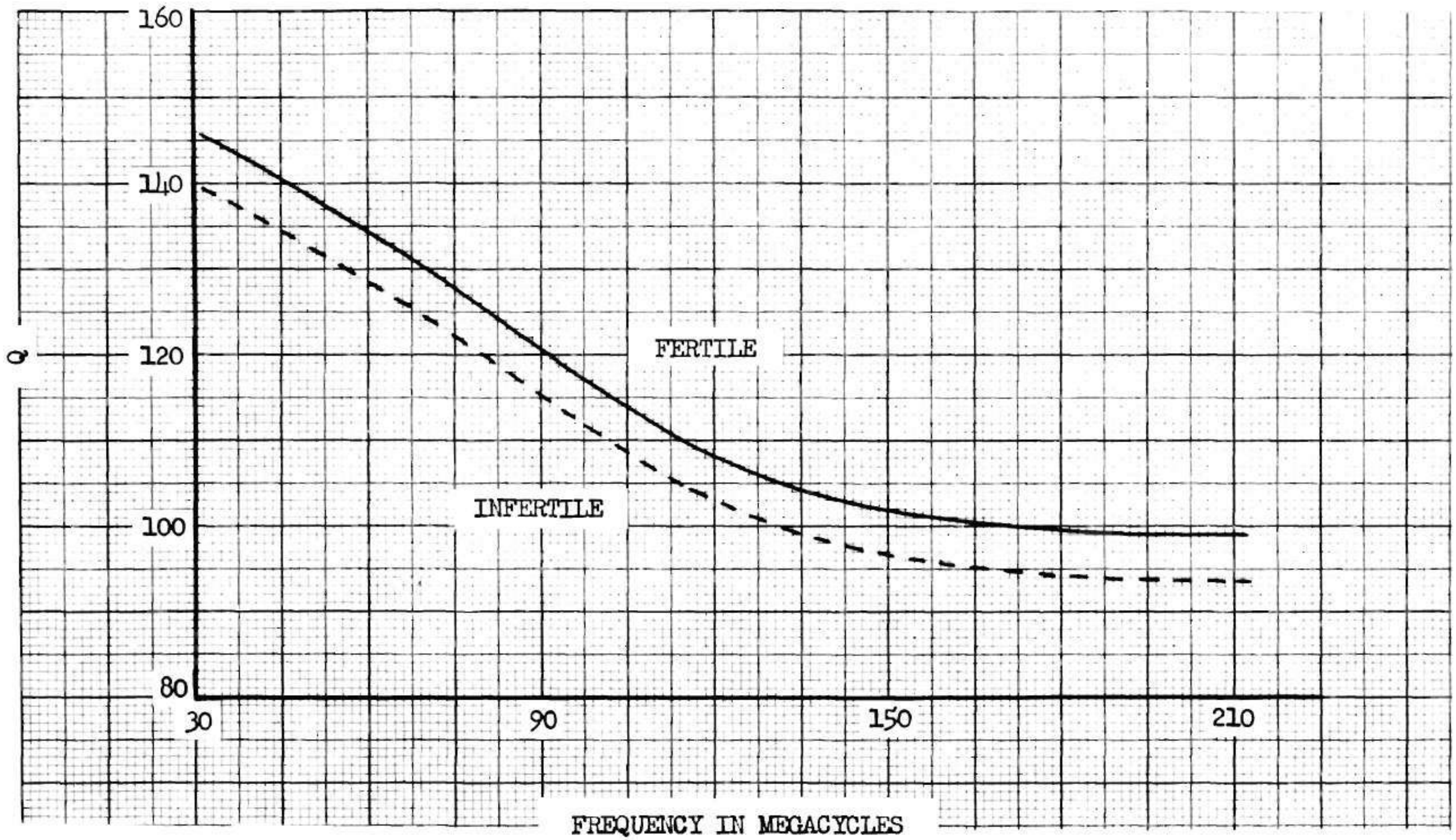

Fig. 5

PLOT OF Q VS. FREQUENCY FOR 27 OZ./DOZEN CHICKEN
EGGS AS MEASURED WITH BOONTON Q-METERS 160A & 170A

CHAPTER IV

DIELECTRIC MEASUREMENTS AT 500 MEGACYCLES

Measurements made on the chicken egg at low frequencies, as described in Chapter III, indicate that the differences in the dielectric properties of fertile and infertile eggs possibly increase as the frequency of measurement is increased. In order to investigate this, the system of dielectric measurement shown in Figure 6 was constructed.

The oscillator employed a type 955 acorn tube in conjunction with a transmission line resonant circuit. Connected across the resonant circuit was a test cell to hold the egg to be measured. This cell was constructed by imbedding two brass plates, one inch long and one-half inch high, in a paraffin egg cradle. The plates were placed on opposite sides of the cradle and in such a manner that their centers, and the egg's center, coincided. When no egg is present in the test cell, the frequency of the oscillator was determined by the interelectrode capacity of the oscillator tube, the distributed capacity of the transmission line, the capacity of a small variable capacitor connected across the line, and by the capacity of the empty test cell. Placing an egg in the test cell has the effect of replacing the air dielectric between the plates with that of the egg. The capacity of the cell was increased and the frequency of the oscillator was reduced. The frequency shift of the oscillator is proportional to the dielectric constant of the egg.

Detection of this frequency shift was accomplished by an inductively coupled resonant circuit whose output was rectified by a type IN34

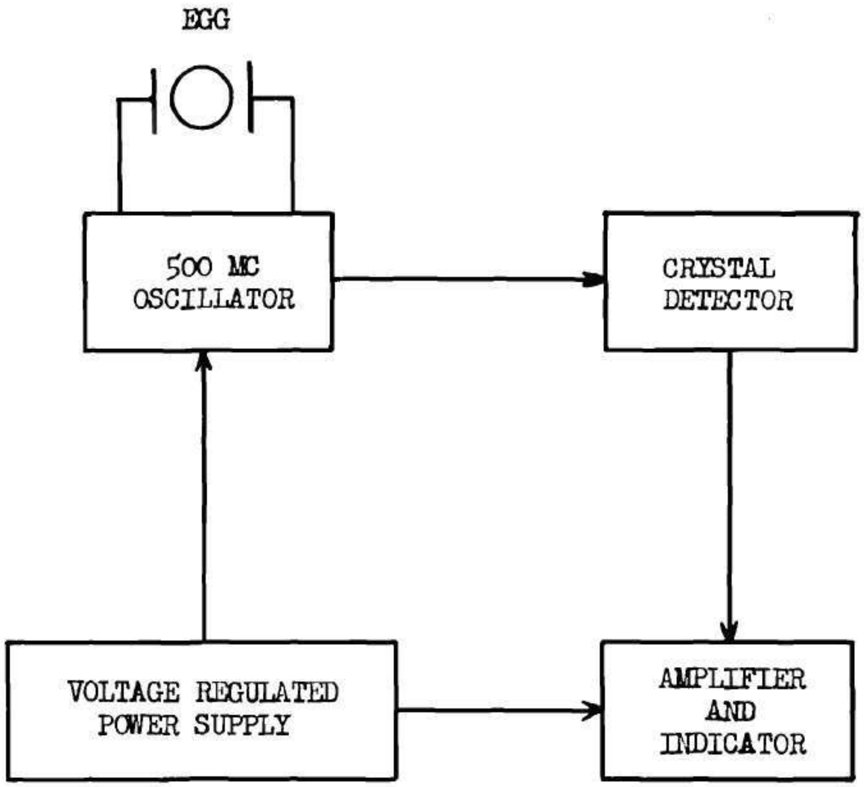

Fig. 6

BLOCK DIAGRAM OF SYSTEM USED TO MEASURE
DIELECTRIC CONSTANT OF AN EGG AT 500 MC

Germanium diode. The detector circuit was resonated at a frequency below that of the oscillator so that, when an egg was placed in the test cell, the frequency of the oscillator would approach that of the detector. This arrangement would cause the voltage to rise across the detector's resonant circuit and give an increased output voltage.

Amplification of the detector output voltage was accomplished by the use of a resistance-capacity coupled amplifier whose output was displayed on a microvoltmeter.

A voltage-regulated power supply was employed to supply power to the oscillator and amplifier. Frequency stability of the oscillator was of extreme importance in that the dielectric constant of the egg must be the only factor to cause a frequency shift. Also, the gain of the amplifier must be constant to prevent error in the readings.

Details of the construction may be seen in Figure 7. The egg cell is located at the top of the figure. Directly below it is the oscillator and to the right is the detector. The shielding, which prevented body capacity from affecting the oscillator, has been removed from the unit.

Dielectric constant measurements were attempted on known infertile and probable fertile eggs. Although weight was compensated for, large errors resulted in the measured data. The known difference in conductivity between fertile and infertile eggs would cause an error in the readings by changing the Q of the oscillator's resonant circuit. This, in itself, could not be responsible for the magnitude of error which resulted. Further investigation revealed that by rotating the egg about its longitudinal axis, a large change in reading could be produced. This property of the egg shall be referred to hereafter as polarization.

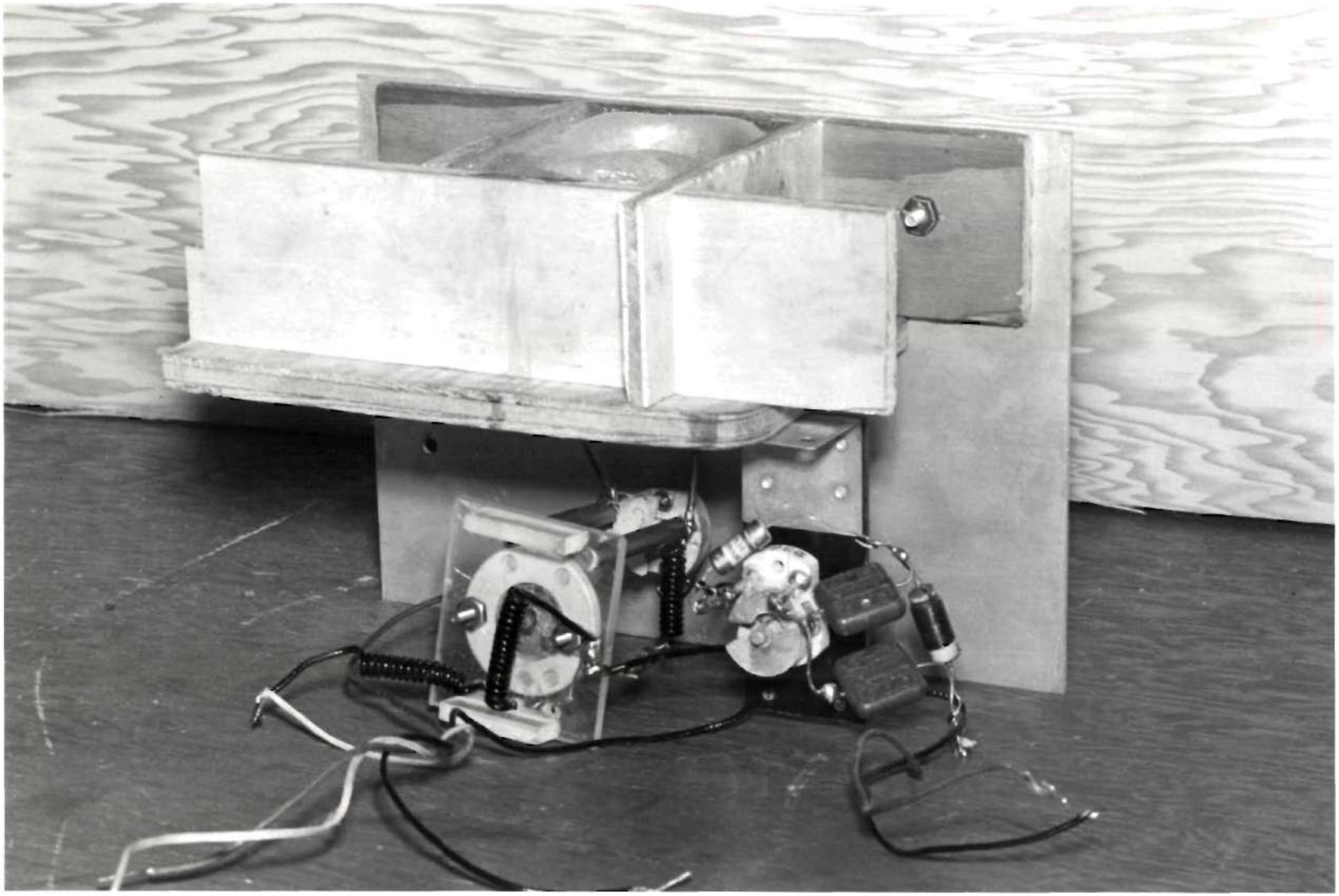

Fig. 7 SYSTEM USED TO MEASURE DIELECTRIC CONSTANT OF AN EGG AT 500 MC

Eggs that exhibited the largest amount of polarization were chosen for study. The contents were carefully removed from several of these eggs and the shells were measured for polarization. No polarization of the shell could be detected. Examination of the interior of other polarized eggs, by a light beam passing through them, indicated that the eccentricity of the yolk caused polarization.

Data taken on known infertile and probable fertile eggs by this system of measurement are not presented in this dissertation, as no means could be found to correct the dielectric readings for the effect of polarization.

CHAPTER V

DIELECTRIC MEASUREMENTS AT 10,000 MEGACYCLES

Based on the assumption that an increase in the difference between the dielectric properties of fertile and infertile eggs occurs with an increase in frequency, measurements were made in the region of 10,000 megacycles. Due to the short wavelength in this microwave region, only a selected portion of the egg need be placed in the electromagnetic field. This affords a means of reducing some of the many variables associated with the problem of determining fertility. By propagating energy through the center section of the egg, the effect of the size of the air cell is eliminated. The length of the egg is no longer of major importance.

Dielectric constant measurements were attempted on fertile and infertile eggs by employing the system of measurement shown in Figure 8. A type 723 A/B reflex klystron, modulated at one kilocycle, was used to generate radio-frequency energy at approximately 10,000 megacycles. This energy was propagated through a rectangular waveguide in the $TE_{1,0}$ mode (9). A slotted line detector was connected to this waveguide for measurement of standing waves. The egg under measurement terminated the slotted line.

Energy was taken from the slotted line by an E field probe and rectified by a type IN21A Silicon crystal diode. This voltage was amplified by a Hewlett-Packard Model 415B Standing Wave Indicator. The output indication was displayed on a microammeter in lieu of the meter on the standing wave indicator, as its scale is logarithmic.

Regulated voltage was supplied to the klystron to keep its fre-

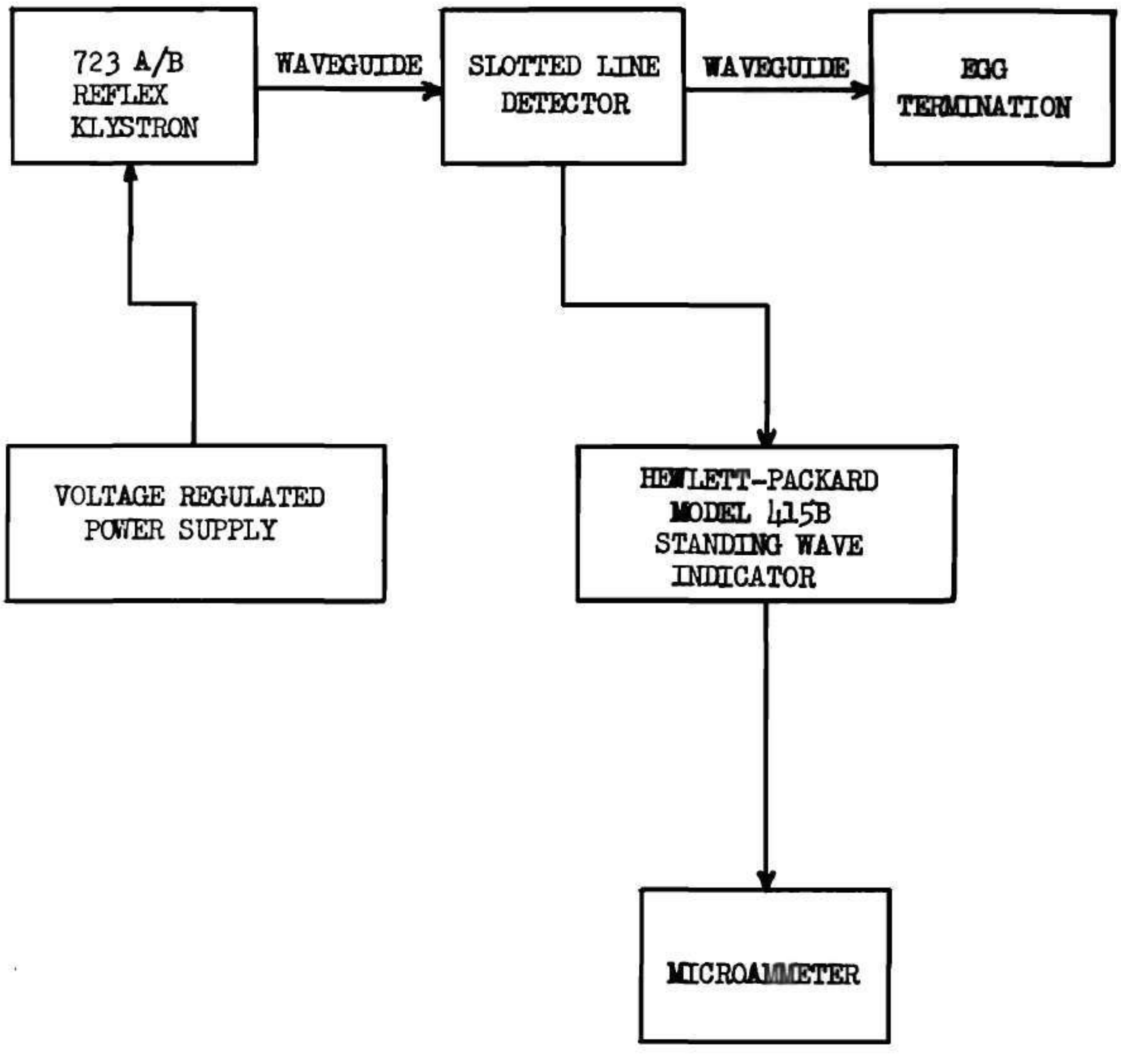

Fig. 8

BLOCK DIAGRAM OF SYSTEM USED FOR DIELECTRIC
MEASUREMENTS OF AN EGG AT 10,000 MC

quency of oscillation constant. Frequency instability would result in a changing standing wave pattern and create error in the dielectric readings.

Figure 9 shows the physical arrangement of the measuring system. The egg under measurement was held in a paraffin cradle with its longitudinal axis parallel to the wide dimension of the waveguide. The ends of the waveguides are located one-half inch from the egg. There was no physical connection between the egg and the waveguide, in order to prevent the flow of conduction current. Other positions for the egg were tried, but the one described proved most satisfactory. Propagation through the ends of the egg was not deemed practical, due to the extereme curvature of the shell in these regions and due to the variations in the size of air cells between eggs.

Dielectric constant difference readings were made on known infertile and probable fertile eggs by placing an egg in the cradle and adjusting the slotted line probe until a minimum reading was obtained on the microammeter. The minimum point was chosen on the standing wave pattern because a small shift in the pattern will result in a larger change in detector voltage output than if a maximum point had been chosen. Another egg was then placed in the cradle and if it had a different dielectric constant, the phase of the reflected electromagnetic waves would be changed. This would cause a change in the standing wave pattern along the line and produce a subsequent change in the detector output reading.

By noting the change in readings between known infertile and probable fertile eggs, it was possible to see that the readings were a function of egg weight and that polarization was also present. An add-

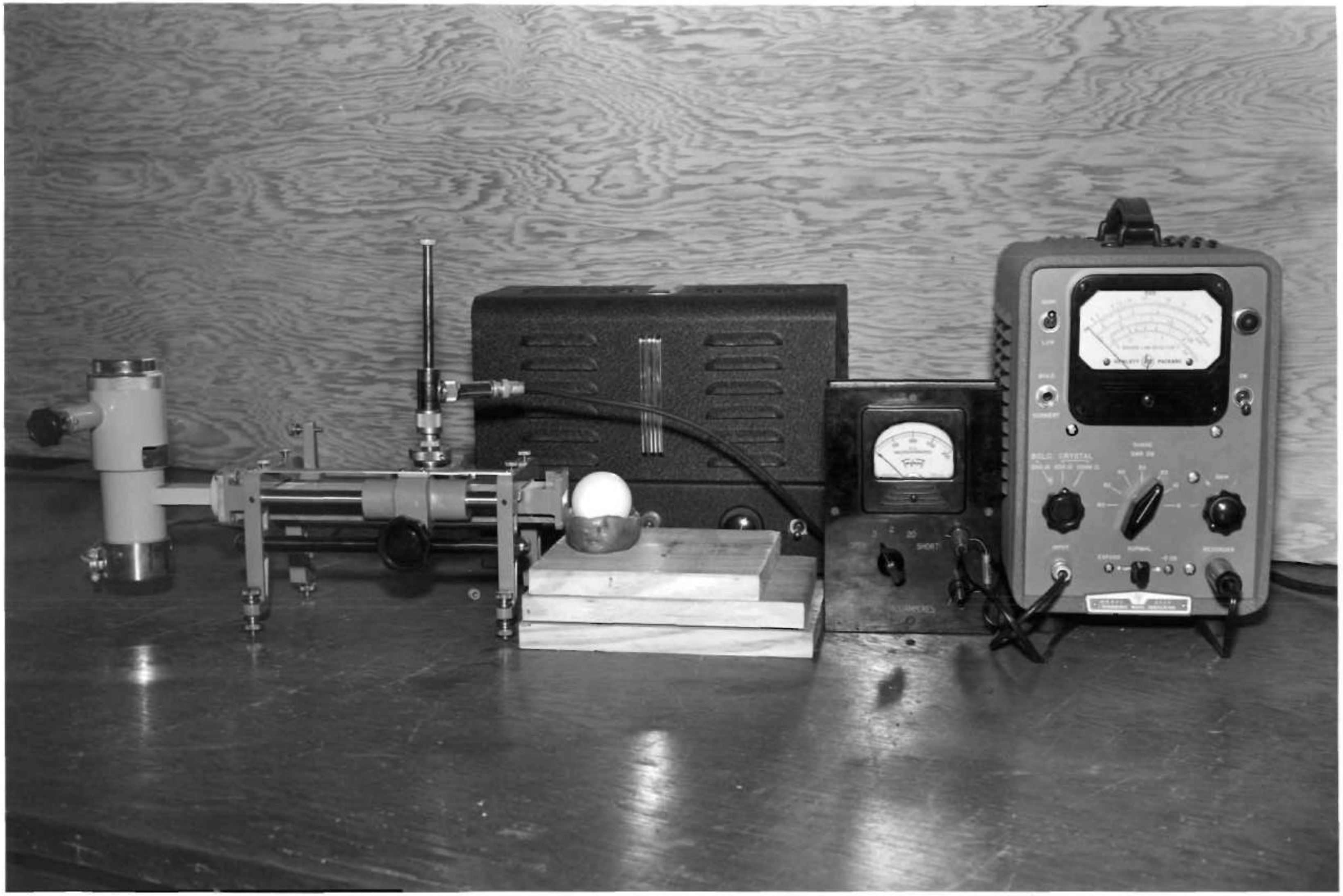

Fig. 9 SYSTEM USED FOR DIELECTRIC MEASUREMENTS OF AN EGG AT 10,000 MC

itional source of error results from the difference in the conductivity between fertile and infertile eggs. The conductivity determines the amount of energy that will be dissipated within the egg and thus affects the amount reflected. Readings taken on eggs by this system of measurement are not presented in this dissertation, as the effect of polarization could not be compensated.

It was noted in earlier experiments that the amount of energy transmitted through the egg was several times larger than the amount reflected. Transmitted energy is equal to the incident energy, less the reflected and dissipated energy. Polarization has an effect on the magnitude of the reflected energy. Since the reflected energy forms only a small part of the transmitted energy, the effect of polarization on the transmitted energy is negligible.

With this idea as a basis, the system for measuring the transmission through fertile and infertile eggs, as shown in Figure 10, was constructed. The system employed the same source for microwave energy as described earlier. This energy was propagated through an egg and entered a short section of waveguide where it was detected by a type IN23 Silicon crystal diode. Amplification and display of the detector output voltage was accomplished in the same manner as described earlier.

Several positions for the egg, with respect to the waveguide, were tried. The most satisfactory results were obtained when the longitudinal axis of the egg was parallel to the wide dimension of the waveguide, as shown in Figure 11.

The electromagnetic energy that is incident to the egg sees a nonhomogeneous, nonisotropic, media in which there are at least 30 different

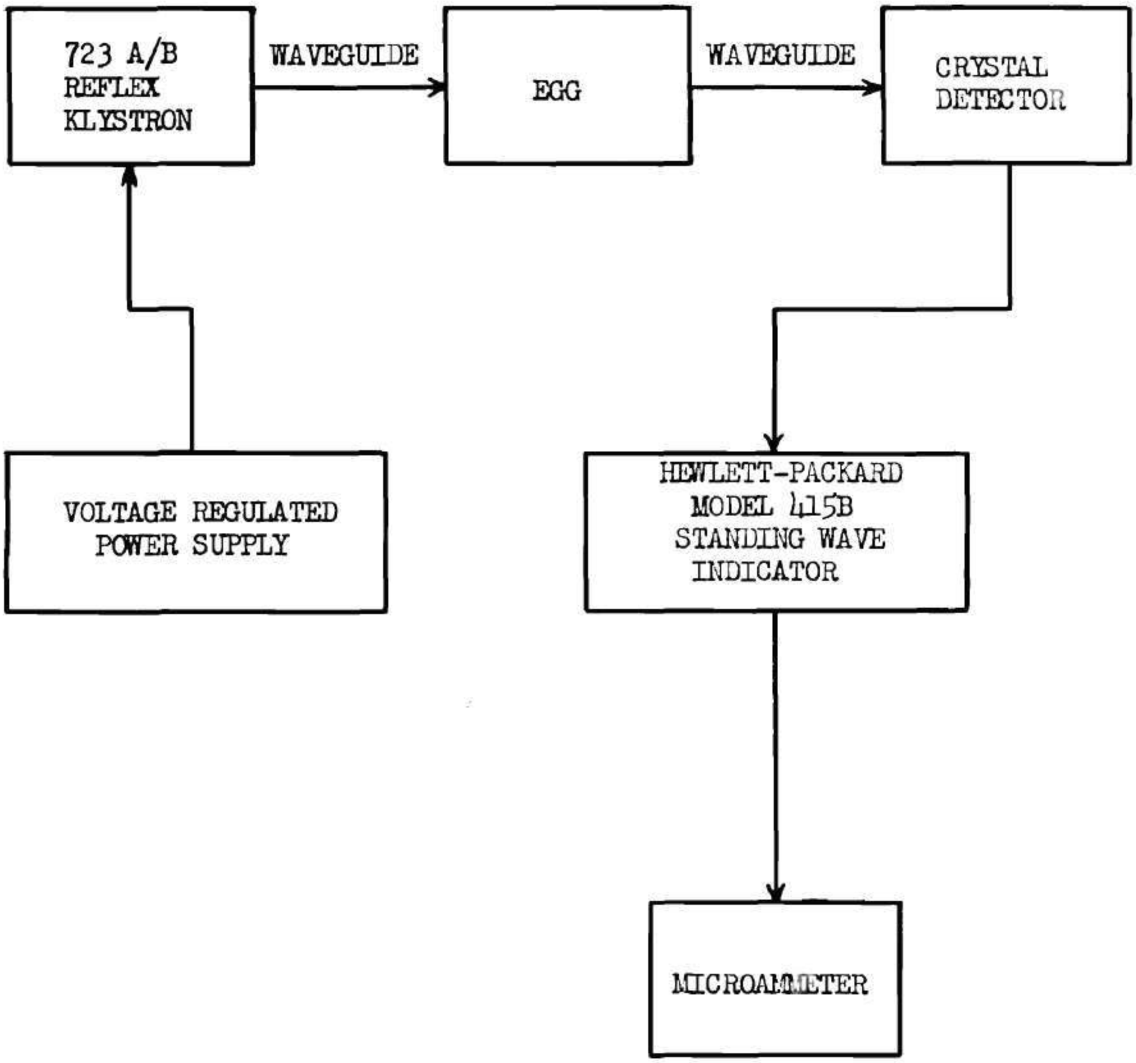

Fig. 10

BLOCK DIAGRAM OF SYSTEM USED TO MEASURE
TRANSMISSION THROUGH AN EGG AT 10,000 MC

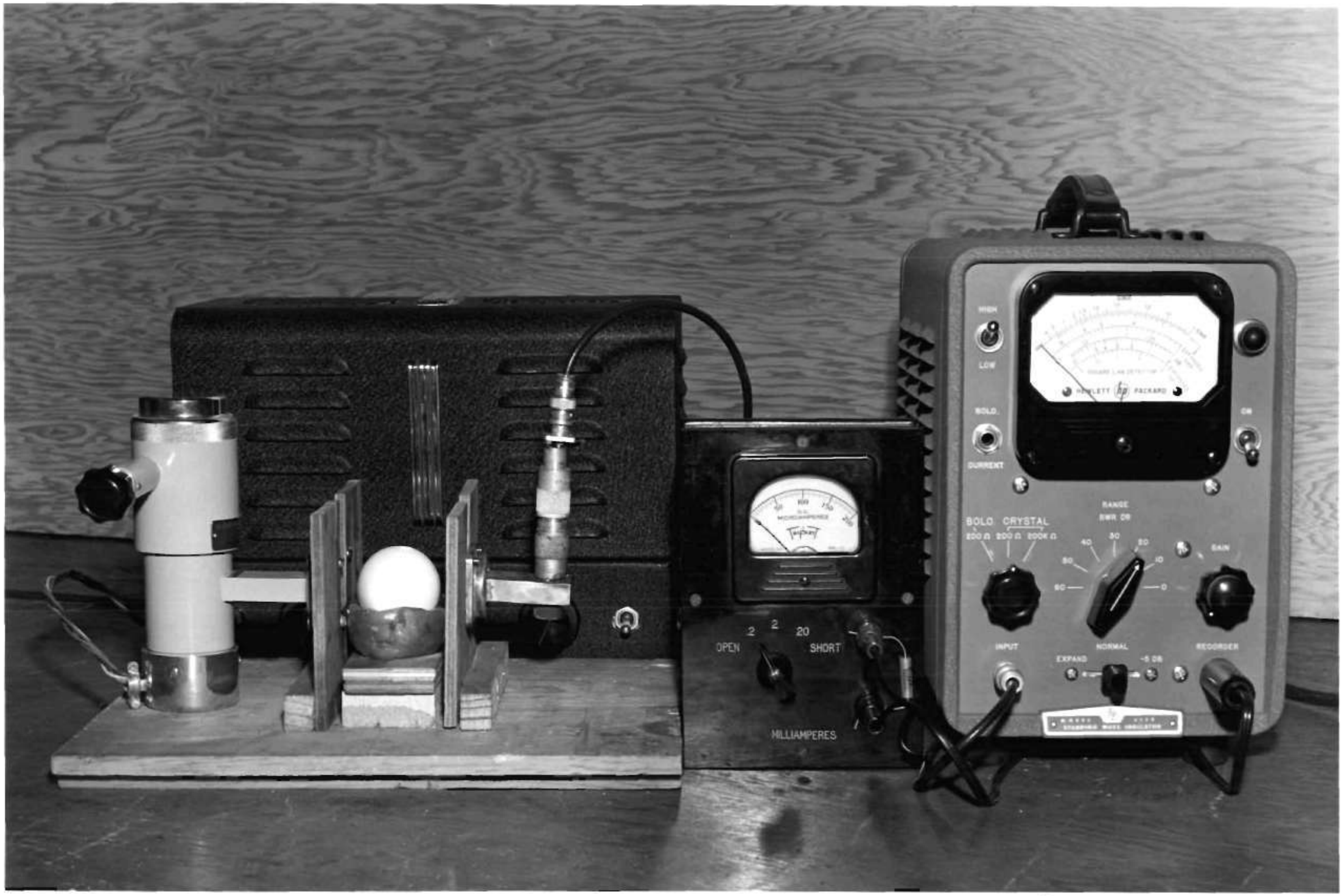

Fig. 11 SYSTEM USED TO MEASURE TRANSMISSION THROUGH AN EGG AT 10,000 MC

boundaries. Each one of these boundaries, as shown in Figure 1, has a different dielectric constant and conductivity. Reflection occurs at each boundary and power dissipation occurs in each region between them. These properties also cause a scattering of energy throughout the egg. Measurable amounts of energy were detected over the entire surface of the egg, however, the maximum energy was propagated directly through the egg.

The transmission property of the egg will be a function of its dielectric constant and conductivity. Since it has been established that the dielectric constant and conductivity of an egg are a measure of its fertility, the transmission property will be also.

To definitely establish the relation of transmission to fertility, a test hatch of probable fertile eggs was conducted. Transmission readings were taken on 360 White Cornish male over No. 12 Nichols Red Female eggs. Each egg was numbered with a grease pencil and its weight and transmission reading was recorded. After 18 days of incubation, the infertile eggs were removed and their numbers recorded.

The average transmission readings for both fertile and infertile eggs are plotted as a function of weight in Figure 12. Some error still exists in these data, as the effect of polarization, though greatly reduced, is still present. Also, the diameter of the egg influences the amount of energy that is transmitted through the egg.

A second test hatch was conducted to determine the effect of the length and diameter of the egg on the transmission readings. Measurements of weight, length, diameter, and transmission were made on 360 White Cornish male over No. 12 Nichols Red Female eggs. These data are

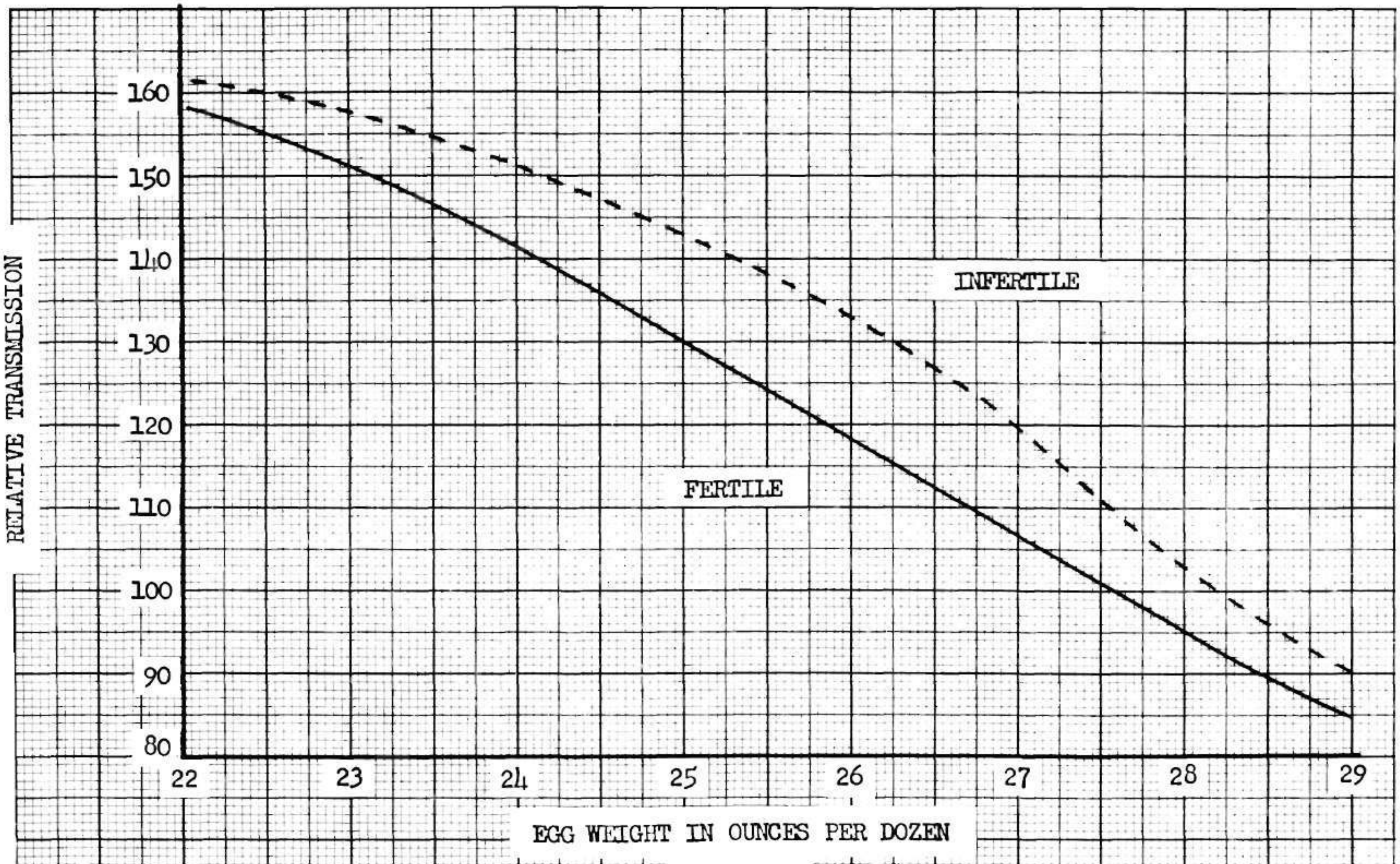

Fig. 12

PLOT OF RELATIVE TRANSMISSION VS. WEIGHT FOR WHITE
CORNISH MALE OVER #12 NICHOLS RED FEMALE EGGS AT 10,000 MC

presented in Table 1. The average transmission readings for both fertile and infertile eggs are plotted as a function of weight in Figure 13. Comparison of Figure 12 to Figure 13 indicates that the curves are similar in shape and that the relative transmission readings for the two hatches are approximately equal.

The effect of egg diameter on the individual transmission readings was obtained by selecting eggs of the same weight and examining their transmission readings as a function of diameter. The transmission readings were found to decrease in an approximately linear manner as the diameter increased. This result was to be expected as the distance through which electromagnetic waves propagate influences the amount of energy transmitted in a dielectric media.

Examination of the effect of egg length on the individual transmission readings was made by selecting eggs of the same weight and diameter and observing their transmission readings as a function of length. The transmission readings were found to increase in an approximately linear manner as the egg length increased. No explanation for this relation between the egg length and transmission can be offered.

Figure 14 shows the distribution of fertile and infertile eggs in the 24 ounce per dozen weight group of the second test hatch. It may be seen that there is no clear dividing line between the fertile and infertile egg readings. The effect of egg diameter and length variation may be responsible for most of this scattering. These variables are not responsible for all the scattering. The transmission readings of eggs having the same fertility, weight, diameter, and length were found to be scattered. This indicates the presence of other variables that have not been determined.

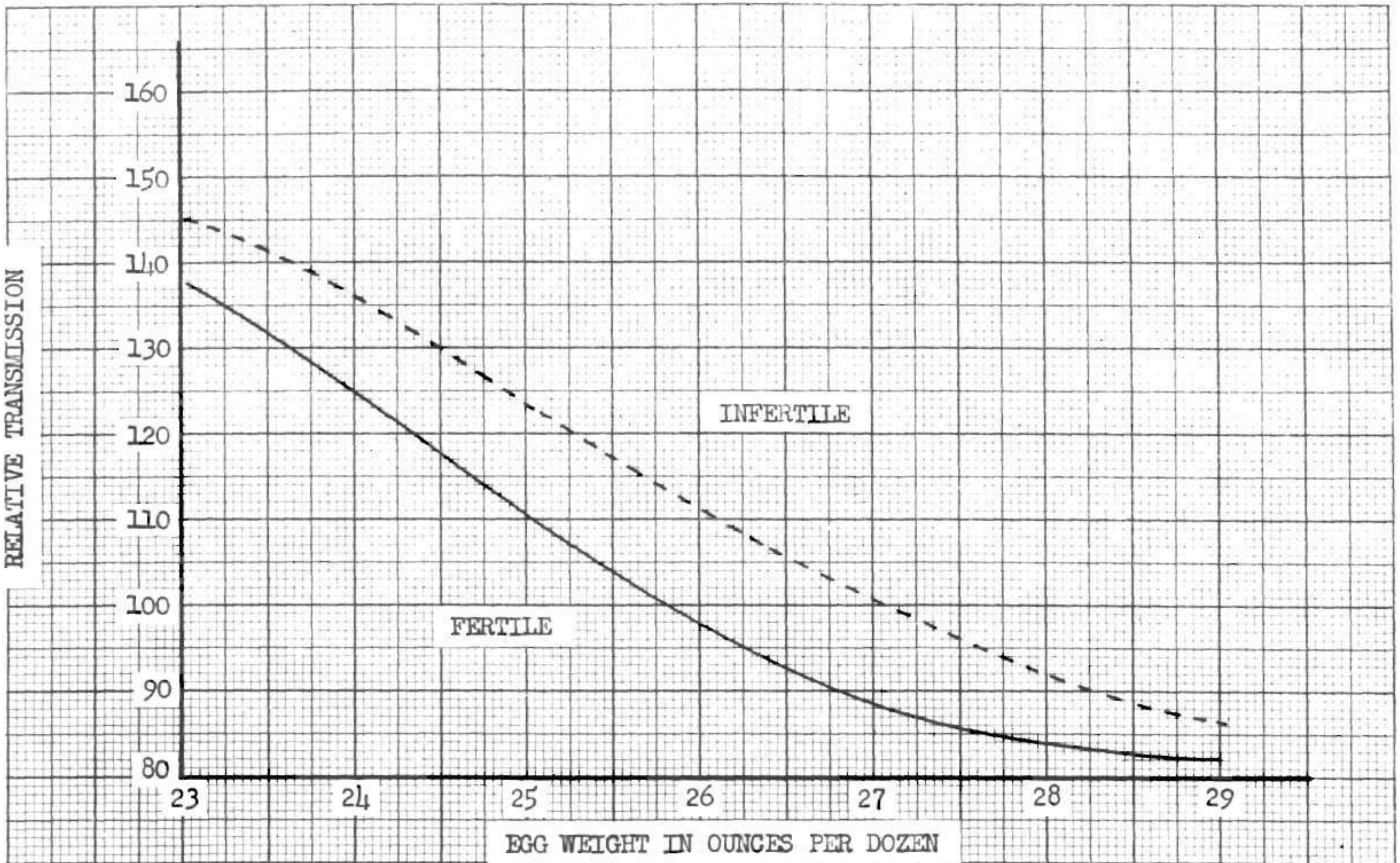

Fig. 13

PLOT OF RELATIVE TRANSMISSION VS. WEIGHT FOR WHITE CORNISH MALE OVER #12 NICHOLS RED FEMALE EGGS AT 10,000 MC

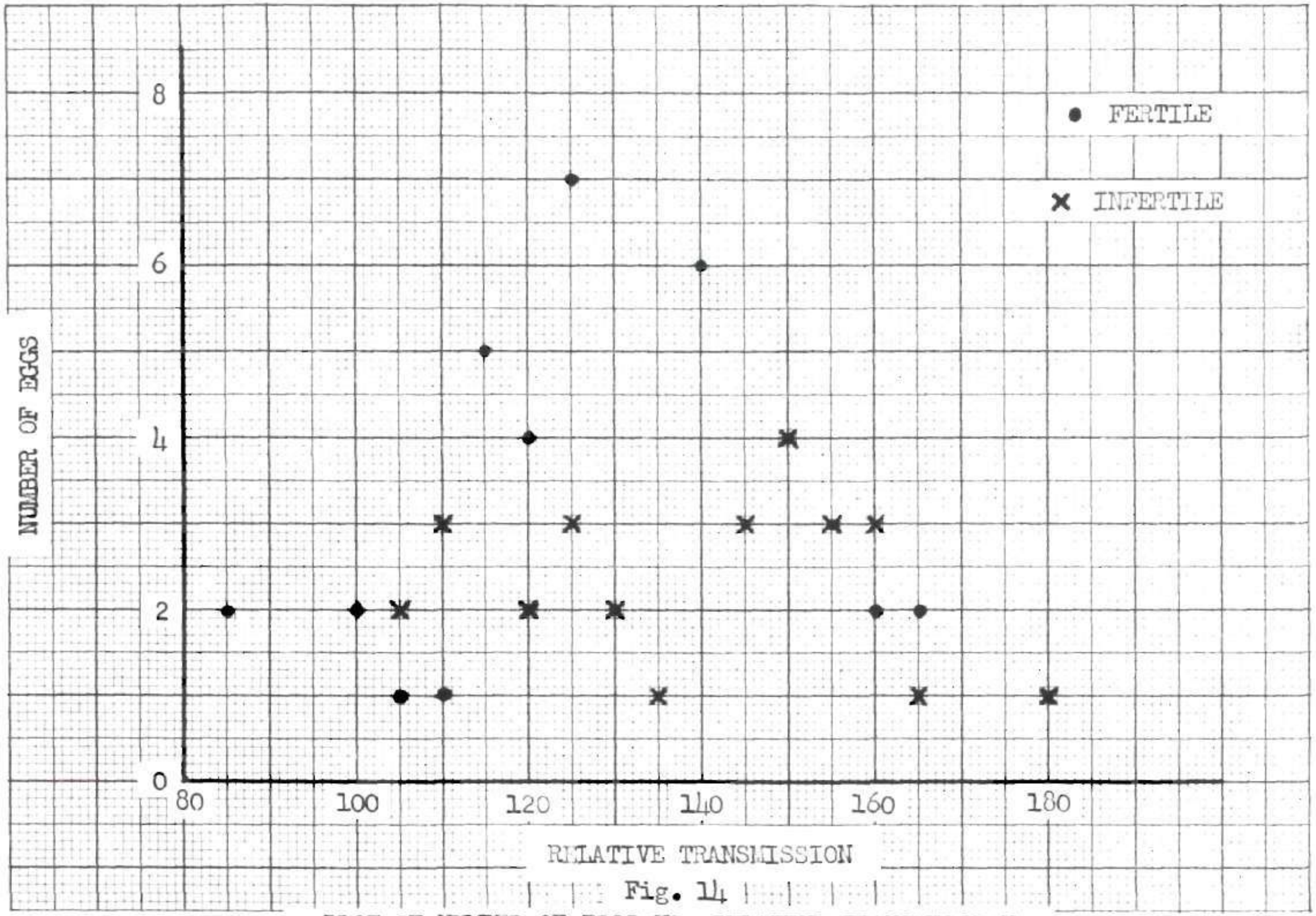

Fig. 14

PLOT OF NUMBER OF EGGS VS. RELATIVE TRANSMISSION
FOR 24 OUNCE PER DOZEN WEIGHT EGGS AT 10,000 MC

An attempt was made to correct the transmission readings for the effect of egg size. This was done by multiplying the transmission readings of eggs of the same weight by the ratio of their diameter to length, and dividing by the ratio of average diameter to average length. A distribution of the corrected readings for the 24 ounce per dozen weight group was plotted and compared to Figure 14. This comparison indicated only a slight reduction in the scattering of the transmission readings. Other variables appear to be responsible for the scattering and no means could be found to compensate for them.

It was not possible to detect all the infertile eggs in a given lot by this system of measurement. In order to remove a majority of infertile eggs, an almost equal number of fertile eggs would also be removed, which makes this system undesirable.

CHAPTER VI

CONCLUSIONS

Power dissipation measurements on fertile and infertile eggs, as described in Chapter III, were found unsatisfactory for determining fertility. The readings obtained were found to be not only dependent upon fertility, but also upon egg weight, egg size, and the position of the egg within the electromagnetic field.

Measurements employing a Q-Meter, as described in Chapter III, indicated that fertile eggs have a higher dielectric constant and a lower electrical conductivity than infertile eggs. This system of measurement also indicated that the difference between the dielectric properties of fertile and infertile eggs increases with frequency. Q-Meter measurements are considered impractical as a means of determining egg fertility due to the expense of the equipment, low sensitivity, and the complexity of measurement.

The system of dielectric constant measurement at 500 megacycles, as described in Chapter IV, proved unsatisfactory as a means of determining egg fertility. Although the system possessed a high degree of sensitivity and was relatively economical to construct, the polarization property of eggs made it useless. Polarization was found to be due to the eccentricity of the yolk and varied from egg to egg.

Dielectric constant readings made at 10,000 megacycles, by employing microwave measurement techniques, proved to be of little value in determining egg fertility. The system of measurement, as described in

Chapter V, was sensitive to differences between eggs but was adversely affected by polarization.

The transmission property of eggs was investigated at 10,000 megacycles, as described in Chapter V. Since the dielectric constant and conductivity of an egg is a measure of its fertility, the transmission property is also. Verification of this was made by two test hatches. Infertile eggs had a higher relative transmission, on the average, than did fertile eggs.

Transmission readings were found to be not only dependent upon fertility but also upon egg weight, egg size, and polarization. The polarization effect is small in this system of measurement and can be considered negligible for most eggs.

The transmission readings of eggs of the same weight were found to decrease as the diameter increased, and to increase as the length increased.

Transmission readings for fertile and infertile eggs of the same weight were found to be scattered, and no precise dividing line existed between them. An attempt to correct the readings for the effect of length and diameter was made by multiplying the transmission reading by the diameter to length ratio and dividing by the average diameter to length ratio. This correction resulted in a slight reduction of the scattering, but indicated that there are other variables producing differences in the transmission readings. Transmission readings for eggs having the same fertility, weight, diameter, and length were found to be scattered. This offers further indication that there are other variables present that are affecting the transmission readings.

It was not possible to detect all infertile eggs in a given lot by this system of measurement. In order to remove a majority of infertile eggs, an almost equal number of fertile eggs would also be removed. This makes the system undesirable from the economic point of view.

Hatchability was high on the test hatches, which indicates that the embryo was not adversely effected by radio-frequency irradiation.

The chicken egg is a highly complex structure about which many things are, as yet, unknown. Determination of fertility by means of dielectric measurements is a problem that is far from being solved. In this investigation, systems of measurement were employed that revealed the variables of weight, size, position, and polarization. These variables must either be eliminated or compensated for before a successful means of dielectric fertility detection can be realized. It is recommended that in future work only eggs of the same weight, diameter, and length be used.

A P P E N D I X

Table 1. Measured Data for Second Test Hatch of White Cornish Male Over #12 Nichols Red Female Eggs

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
1	24.0	150		5.8	4.3
2	23.5	125		5.2	4.3
3	24.5	120	X	5.7	4.3
4	25.5	145	X	5.8	4.3
5	23.5	150	Cracked	5.7	4.0
6	26.0	95	X	5.7	4.4
7	24.0	150	X	5.8	4.0
8	25.0	140		5.7	4.3
9	24.5	150		5.8	4.2
10	25.0	140	X	5.8	4.3
11	24.5	115		5.6	4.3
12	24.0	120	X	5.4	4.3
13	24.0	130	X	5.6	4.3
14	24.0	160		5.8	4.1
15	24.5	130		5.7	4.3
16	25.5	125	X	5.7	4.4
17	23.5	165	X	5.9	4.0
18	25.0	120		5.7	4.4
19	23.5	145		5.7	4.2
20	24.5	90		5.7	4.4
21	23.5	145		5.5	4.3
22	26.5	130	X	6.3	4.2
23	26.5	75		5.5	4.5
24	24.0	145		5.7	4.1
25	27.0	100		6.0	4.4
26	23.5	125	X	5.4	4.4
27	23.0	135		5.5	4.3
28	25.5	105	X	5.6	4.4
29	24.0	145	X	5.7	4.2
30	24.0	130		5.6	4.2
31	25.0	115		5.8	4.4
32	24.0	130	X	5.6	4.3
33	23.5	120		5.6	4.2
34	25.0	120		5.7	4.3
35	27.5	80	X	5.7	4.5
36	24.0	155		5.7	4.2
37	27.0	105	X	5.7	4.4
38	26.5	100	X	5.8	4.5

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
39	25.0	100	X	5.5	4.3
40	25.0	85		5.4	4.4
41	26.0	85		5.8	4.4
42	25.5	115		5.7	4.4
43	26.0	85	X	5.6	4.4
44	27.0	65	X	5.6	4.5
45	26.5	115		5.7	4.3
46	25.5	115	X	5.7	4.4
47	27.5	85		5.7	4.5
48	27.0	70		5.6	4.5
49	28.5	90	X	6.0	4.5
50	25.0	110	X	5.7	4.4
51	25.0	120		5.8	4.4
52	24.0	160	X	5.7	4.2
53	24.0	140		5.6	4.2
54	24.0	145		5.7	4.2
55	24.5	155	X	5.7	4.2
56	25.0	115	X	5.7	4.3
57	25.0	115		5.5	4.4
58	28.5	80		5.8	4.5
59	25.0	115	X	5.5	4.4
60	28.0	90		5.9	4.4
61	25.0	140	X	5.8	4.4
62	24.0	155		5.7	4.2
63	25.0	85		5.3	4.5
64	24.0	125		5.4	4.4
65	28.5	75		5.8	4.5
66	24.0	150	X	5.6	4.3
67	25.0	150		5.7	4.3
68	28.5	110		6.0	4.4
69	24.0	125		5.7	4.3
70	25.5	100		5.6	4.4
71	25.0	115		5.6	4.4
72	23.5	115		5.3	4.4
73	24.0	155	X	5.6	4.2
74	23.5	150	X	5.2	4.4
75	28.0	100	X	5.8	4.5
76	24.5	125	X	5.6	4.4
77	26.0	120		5.8	4.4
78	24.5	140		5.6	4.2
79	28.0	115		6.1	4.4
80	25.0	140		5.7	4.2
81	26.0	65		5.3	4.5

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative trans-mission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
82	27.0	100	X	5.8	4.5
83	25.0	105	X	5.6	4.4
84	24.5	100	X	5.3	4.3
85	26.5	100		5.8	4.4
86	24.5	160	X	5.8	4.2
87	24.5	85		5.3	4.5
88	24.0	140		5.7	4.3
89	25.5	125		5.7	4.3
90	26.0	105		5.5	4.4
91	24.0	125	X	5.7	4.3
92	26.5	100	X	5.8	4.4
93	23.0	160	Cracked	5.6	4.2
94	26.5	85	X	5.8	4.5
95	25.0	105		5.4	4.4
96	26.0	80	X	5.6	4.5
97	24.0	165		6.0	4.1
98	24.5	125		5.7	4.3
99	25.0	110	X	5.4	4.4
100	24.0	120		5.3	4.4
101	25.0	150		5.7	4.2
102	27.5	110		5.7	4.4
103	27.0	120	X	5.8	4.4
104	27.0	100		5.7	4.5
105	23.5	125		5.7	4.3
106	23.5	130	X	5.4	4.3
107	25.5	130		5.8	4.1
108	26.0	90		5.6	4.4
109	25.0	145	X	5.8	4.2
110	24.0	120	X	5.3	4.4
111	24.0	115		5.5	4.3
112	23.5	110		5.2	4.4
113	26.0	115	X	5.8	4.4
114	24.5	120		5.4	4.4
115	25.5	90		5.6	4.5
116	25.5	80	X	5.4	4.4
117	24.5	130	X	5.7	4.3
118	23.5	145	X	5.6	4.4
119	24.5	135		5.7	4.3
120	24.5	135		5.7	4.4
121	24.0	155	X	5.7	4.1
122	26.0	100	X	5.5	4.4
123	25.0	115		5.6	4.4
124	27.0	85		5.8	4.4

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
125	24.0	115		5.4	4.4
126	28.0	75		5.7	4.5
127	27.0	55	X	5.4	4.7
128	25.5	130		5.8	4.4
129	28.5	105		6.2	4.4
130	23.5	135		5.5	4.3
131	24.0	135	X	5.5	4.3
132	30.0	85		6.2	4.5
133	24.5	135		5.7	4.3
134	24.5	115		5.6	4.4
135	30.0	70		6.0	4.6
136	31 +	45		6.0	4.8
137	24.5	110		5.6	4.4
138	23.5	125		5.4	4.4
139	25.0	150		5.8	4.3
140	25.0	115		5.5	4.4
141	28.5	65	X	5.7	4.6
142	27.5	85		5.8	4.5
143	26.0	120		5.7	4.4
144	24.0	115		5.4	4.4
145	23.5	170		5.7	4.1
146	25.5	100		5.7	4.4
147	24.0	95	X	5.3	4.4
148	23.0	155	X	5.4	4.2
149	27.5	65		5.7	4.6
150	23.0	110		5.2	4.4
151	25.5	135		5.8	4.3
152	24.0	160		5.8	4.2
153	23.5	120		5.3	4.4
154	23.5	140		5.6	4.3
155	23.0	150		5.4	4.2
156	24.0	140		5.6	4.3
157	26.0	100	X	5.5	4.4
158	23.0	160	X	5.7	4.1
159	24.5	135		5.7	4.3
160	27.0	105		5.8	4.4
161	24.5	110		5.6	4.4
162	25.5	105		5.7	4.4
163	25.5	110	X	5.7	4.4
164	25.0	110		5.7	4.4
165	24.0	105		5.6	4.3
166	24.0	160	X	5.8	4.2
167	24.5	100		5.4	4.4

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
168	28.5	100	X	6.0	4.5
169	25.0	125		5.7	4.3
170	23.5	125	X	5.5	4.3
171	24.0	120		5.4	4.4
172	23.5	130	X	5.4	4.3
173	24.0	150	X	5.6	4.3
174	26.0	105		5.5	4.5
175	27.0	100		5.8	4.4
176	24.5	115		5.4	4.4
177	26.0	105		5.5	4.4
178	25.0	90		5.3	4.5
179	23.5	105		5.3	4.4
180	24.0	110		5.3	4.5
181	23.0	150	X	5.4	4.2
182	24.0	125		5.4	4.3
183	24.0	145		5.6	4.2
184	24.5	115		5.6	4.2
185	24.0	180	X	5.8	4.0
186	24.5	135		5.4	4.3
187	25.0	150		5.8	4.2
188	25.0	135		5.5	4.3
189	24.5	140	X	5.4	4.3
190	26.0	120	X	5.7	4.4
191	24.5	150		5.8	4.3
192	24.0	150		5.5	4.2
193	24.0	85		5.1	4.5
194	26.0	155	X	6.2	4.3
195	24.0	125		5.5	4.2
196	25.0	140	X	5.7	4.3
197	23.0	145		5.4	4.3
198	26.0	135	X	5.8	4.3
199	24.0	150	X	5.7	4.2
200	24.5	110	X	5.6	4.3
201	24.5	155	X	5.7	4.2
202	26.0	100		5.6	4.4
203	25.0	125	X	5.6	4.3
204	23.0	120	X	5.4	4.3
205	23.0	145		5.5	4.2
206	24.5	135		5.7	4.3
207	25.0	150		5.8	4.2
208	24.0	115		5.5	4.3
209	26.0	80		5.7	4.4
210	23.5	120		5.4	4.3

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
211	26.0	70	Cracked	5.6	4.5
212	25.0	120	X	5.5	4.4
213	24.0	155		5.7	4.2
214	25.5	135		5.8	4.3
215	24.0	100		5.3	4.4
216	24.0	145	X	5.7	4.2
217	24.0	125		5.4	4.4
218	24.0	135		5.6	4.3
219	24.0	110	X	5.3	4.4
220	24.0	115	X	5.5	4.4
221	26.5	85	X	5.6	4.5
222	25.0	160	Cracked	5.7	4.2
223	23.5	125	X	5.3	4.3
224	23.5	120		5.3	4.3
225	24.0	115	X	5.3	4.4
226	25.5	75	X	5.4	4.5
227	24.5	100		5.5	4.4
228	24.5	120	X	5.5	4.4
229	24.5	160	X	5.8	4.2
230	24.5	130		5.7	4.3
231	24.5	130		5.8	4.3
232	23.5	125		5.4	4.3
233	25.5	135	X	5.7	4.4
234	25.0	115		5.4	4.4
235	23.5	140		5.4	4.3
236	25.0	75		5.3	4.5
237	24.5	100		5.5	4.4
238	25.5	140	X	5.7	4.3
239	24.0	125		5.5	4.3
240	25.0	130	X	5.7	4.3
241	23.0	140	X	5.5	4.2
242	25.5	90		5.5	4.5
243	25.0	130		5.7	4.3
244	25.5	80		5.4	4.4
245	24.5	125		5.5	4.3
246	25.0	105		5.4	4.4
247	25.0	145		5.8	4.3
248	24.5	90		5.3	4.5
249	23.5	150		5.5	4.3
250	25.5	130		5.7	4.3
251	24.0	140		5.6	4.2
252	24.0	115		5.4	4.4
253	23.5	130		5.4	4.3

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
254	25.0	130	X	5.7	4.3
255	24.0	100	X	5.3	4.4
256	24.0	140		5.5	4.3
257	25.0	85		5.3	4.4
258	25.5	110		5.8	4.4
259	24.0	130		5.5	4.2
260	23.0	135	X	5.3	4.2
261	27.0	125		6.0	4.3
262	25.0	120	X	5.6	4.3
263	26.5	100		5.8	4.4
264	25.5	105	X	5.6	4.4
265	24.5	130		5.6	4.2
266	25.5	105		5.6	4.4
267	27.0	45	X	5.5	4.6
268	23.0	150	X	5.2	4.4
269	27.0	85		5.7	4.4
270	24.0	120		5.5	4.3
271	24.5	90		5.4	4.3
272	24.0	125		5.5	4.3
273	27.0	75		5.5	4.5
274	23.5	115		5.4	4.4
275	24.0	85		5.2	4.4
276	23.5	145	X	5.5	4.2
277	24.5	115	X	5.6	4.3
278	24.0	85		5.2	4.4
279	23.5	145		5.7	4.1
280	25.5	100	X	5.5	4.4
281	27.0	55		5.6	4.6
282	28.0	55		5.6	4.6
283	24.5	120	X	5.5	4.4
284	27.5	115		5.7	4.4
285	24.5	155		5.7	4.2
286	27.0	105		5.8	4.4
287	24.0	100		5.4	4.4
288	26.0	130		5.7	4.3
289	24.0	150		5.6	4.2
290	26.5	110		5.7	4.5
291	24.0	125	X	5.7	4.4
292	26.5	110	X	5.8	4.4
293	25.0	130		5.7	4.2
294	24.0	155	X	5.7	4.2
295	24.5	125		5.6	4.3
296	23.5	90		5.2	4.5

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative transmission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
297	24.5	110	X	5.4	4.4
298	24.5	85		5.3	4.5
299	24.0	115	X	5.4	4.4
300	24.0	110	X	5.5	4.4
301	25.0	105		5.4	4.5
302	26.5	50		5.3	4.7
303	29.0	65	X	5.8	4.6
304	27.0	95	X	5.7	4.4
305	25.5	120		5.6	4.4
306	27.0	90		5.8	4.4
307	27.0	105	X	5.7	4.5
308	28.0	85	X	5.8	4.6
309	24.5	80		5.2	4.5
310	25.0	125	X	5.5	4.4
311	23.0	150		5.4	4.2
312	24.0	145		5.6	4.3
313	26.5	120	X	6.2	4.3
314	24.0	160	X	5.7	4.2
315	26.0	115		5.6	4.4
316	24.5	130		5.5	4.3
317	25.0	125		5.6	4.4
318	24.5	150		5.7	4.3
319	24.5	120		5.5	4.4
320	25.5	140		5.7	4.3
321	24.0	165		5.6	4.2
322	25.0	100	X	5.3	4.5
323	24.5	160		5.8	4.2
324	24.0	125		5.4	4.4
325	27.0	100		5.6	4.5
326	23.5	160	X	5.7	4.2
327	26.5	100		5.7	4.5
328	28.5	60	X	5.6	4.6
329	25.0	120	X	5.5	4.4
330	23.5	120		5.2	4.3
331	28.0	95		5.7	4.5
332	25.0	130	X	5.5	4.4
333	27.5	110	X	5.7	4.5
334	24.0	120		5.3	4.3
335	23.0	140	X	5.3	4.3
336	27.5	100		5.6	4.5
337	25.0	115	X	5.5	4.4
338	24.5	115	X	5.4	4.4
339	25.5	130		5.6	4.4

Table 1. Continued

Egg Number	Weight in ounces per dozen	Relative trans-mission at 10,000 MC	Infertile Eggs	Length in Centimeters	Diameter in Centimeters
340	28.5	105		5.7	4.5
341	25.5	125		5.7	4.4
342	24.0	165	X	5.7	4.2
343	24.0	150		5.4	4.2
344	23.0	160		5.6	4.1
345	25.0	130	X	5.6	4.3
346	26.5	115		5.7	4.4
347	26.0	125	X	5.7	4.4
348	24.0	145	X	5.6	4.3
349	24.0	140		5.5	4.3
350	27.5	100		5.7	4.5
351	24.0	110	X	5.2	4.4
352	26.5	100	X	5.6	4.5
353	23.5	125		5.3	4.4
354	25.5	155		6.0	4.3
355	24.5	90	X	5.3	4.5
356	24.5	170	X	6.0	4.1
357	27.0	70	X	5.6	4.6
358	24.0	150		5.6	4.2
359	26.0	150		6.0	4.3
360	25.0	100	X	5.3	4.5

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